U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS43

Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2

by

PERCY A. SIGLER
and ELMER A. KOERNER

NATIONAL
BUREAU OF STANDARDS

The program of research on building materials and structures, carried on by the National Bureau of Standards, was undertaken with the assistance of the Central Housing Committee, an informal organization of Government agencies concerned with housing construction and finance, which is cooperating in the investigations through a subcommittee of principal technical assistants.

CENTRAL HOUSING COMMITTEE
SUBCOMMITTEE ON TECHNICAL RESEARCH

Walter Junge, *Chairman.*
Federal Housing Administration.

A. C. Shire, *Vice Chairman.*
United States Housing Authority.

Sterling R. March, *Secretary.*

Albert G. Bear,
Veterans' Administration.

Pierre Blouke,
Federal Home Loan Bank Board (Federal Loan Agency).

Carroll W. Chamberlain,
Public Buildings Administration (Federal Works Agency).

Joseph M. DallaValle,
Public Health Service (Federal Security Agency).

John Donovan,
Farm Security Administration (Agriculture).

George E. Knox,
Yards and Docks (Navy).

Vincent B. Phelan,
National Bureau of Standards (Commerce).

Edward A. Poynton,
Office of Indian Affairs (Interior).

George W. Trayer,
Forest Service (Agriculture).

Elsmere J. Walters,
Construction Division (War).

CHAIRMEN OF SECTIONS

Specifications
Carroll W. Chamberlain

Materials
Elsmere J. Walters

Maintenance
John H. Schaefer

Mechanical Equipment
Robert K. Thulman

Methods and Practices
————————

NATIONAL BUREAU OF STANDARDS
STAFF COMMITTEE ON ADMINISTRATION AND COORDINATION

Hugh L. Dryden, *Chairman.*
Mechanics and Sound.

Phaon H. Bates,
Clay and Silicate Products.

Hobart C. Dickinson,
Heat and Power.

Warren E. Emley,
Organic and Fibrous Materials.

Gustav E. F. Lundell,
Chemistry.

Addams S. McAllister,
Codes and Specifications.

Henry S. Rawdon,
Metallurgy.

The Forest Products Laboratory of the United States Department of Agriculture is cooperating with both committees on investigations of wood constructions.

[For list of BMS publications and how to purchase, see cover page III.]

UNITED STATES DEPARTMENT OF COMMERCE · Harry L. Hopkins, Secretary
NATIONAL BUREAU OF STANDARDS · Lyman J. Briggs, Director

BUILDING MATERIALS *and* STRUCTURES

REPORT BMS43

Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2

by

PERCY A. SIGLER
and ELMER A. KOERNER

ISSUED FEBRUARY 13, 1940

The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

UNITED STATES GOVERNMENT PRINTING OFFICE · WASHINGTON · 1940
FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C. · PRICE 10 CENTS

Foreword

In connection with the research program on building materials suitable for low-cost house construction being conducted by the National Bureau of Standards, performance tests have been made on different floor coverings and adhesives in order to determine their relative ability to withstand severe service. Lack of available information on many important factors makes direct comparisons in service difficult.

This report presents the results of tests on a second series of 40 installations in the Bureau's floor-testing chamber, as a supplement to report BMS34. The condition of these installations at the end of the test is discussed and representative photographs are shown. A performance test on a third series of 40 installations is in progress.

LYMAN J. BRIGGS, *Director.*

Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2

by Percy A. Sigler *and* Elmer A. Koerner

CONTENTS

	Page
Foreword	II
I. Introduction	1
II. Floor-testing chamber and equipment	2
III. Test conditions and procedure	3
IV. Description of test installations	3
V. Results	5
VI. Comments	20
VII. Selected references	20

ABSTRACT

In the second series, 40 test installations were subjected to a performance test in the floor-testing chamber of the National Bureau of Standards. Included in the tests were battleship linoleum, rubber in sheet and tile form, felt-base floor coverings having various wearing surfaces, three monolithic floors, and a number of asphalt tiles. The bonding agents used included lignin pastes, resinous cements, latex adhesives, rubber cements, cut-back asphalt, and asphalt emulsions. Installations were made on both concrete and wood subfloors. Descriptions of the testing equipment and test installations are given. Results showing the relative depth of the depressions in the floor coverings during the test are presented in tables. Brief summaries showing the performance of the test panels are given, and the appearance of the different floor coverings after 48,000 cycles of the testing equipment is shown by representative photographs.

I. INTRODUCTION

Durability in relation to cost is important to the consumer confronted with a flooring problem. Often the consumer is willing to sacrifice some durability in order to obtain a floor covering which has decorative appeal or one which possesses a particular characteristic essential to his problem. There are many properties of a floor covering which have a bearing on its durability in service, such as resistance to abrasion, crushing strength, indentation characteristics, tear resistance, aging properties, effect of moisture and temperature, and resistance to cleansing and finishing materials.

In service, floor coverings are subjected to many different types of exposure, and as a result there may be wide variations in the length of service rendered by similar floor coverings. Lack of information on and variations in such important factors as quality of merchandise used, condition of subfloor, method of installation, extent and nature of maintenance, and the magnitude of the exposure and abuses to which the floor covering is subjected make direct comparisons in service difficult.

In a laboratory performance test, it is possible to control many of the factors affecting performance in service. However, it has not been found possible to include all such factors in any one test. In order to obtain results within a comparatively short time, a laboratory test must necessarily be accelerated and severe. The National Bureau of Standards has conducted performance tests on various types of floor coverings and various methods of intallation in connection with a research program on building materials suitable for low-cost house construction [1].[1] This report presents the results obtained on a second series of installations. The results obtained on the first series of installations have been reported in BMS34 [2]. The only alteration in the equipment used in the two series of tests was the substitution of a rubber-tired truck wheel for one of the two steel-rimmed truck wheels used in the first series. No attempt was made to ascertain the effects of such factors, as finishing coats, maintenance, age, moisture, and temperature on the durability or performance of the test installations.

---

[1] Figures in brackets indicate the literature references at the end of this report.

The testing equipment was a modification of that previously used in a study of industrial-type floors for the Procurement Division of the Treasury Department [3]. The materials tested represented good-quality merchandise in the lower-cost grades of each type. The generous cooperation of manufacturers in furnishing materials for test is gratefully acknowledged.

Laboratory investigations are also being conducted on the various floor coverings and adhesives to determine their relative merits with respect to pertinent properties, as outlined in NBS Letter Circular LC502 F [4, 5].

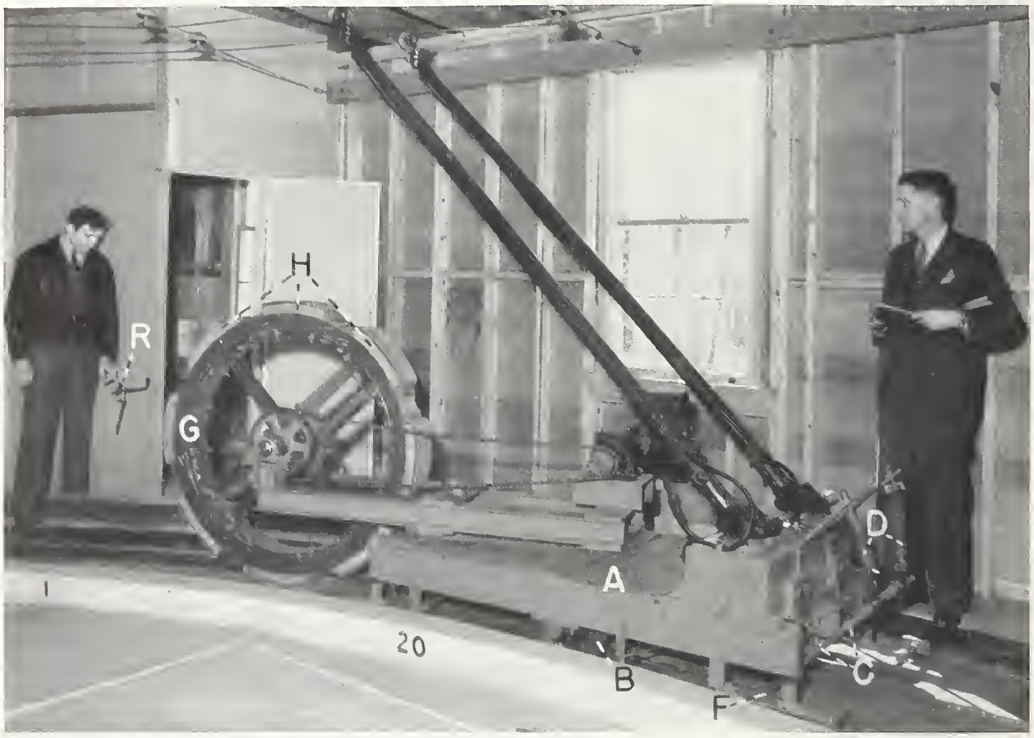


FIGURE 1.—*Floor-testing equipment.*

II. FLOOR-TESTING CHAMBER AND EQUIPMENT

The floor-testing chamber contains a concrete circular track 4 ft wide, $8\frac{1}{2}$ in. thick, and approximately 40 ft in diam, with a metal-shod concrete curb on each side. The circular track is divided into 20 test spaces by metal thresholds, the surfaces of which are 4 in. above the structural slab. Wood or concrete subfloors and the various floor coverings and adhesives were installed in these spaces for test. Two different installations, 3 ft long, were made in each test space.

Figure 1 shows a portion of the circular track and the testing equipment used in this performance test. The equipment consisted of a platform truck, *A*, equipped with two wheels 12 in. in diam. The inner wheel, *B*, had a solid rubber tire, $2\frac{1}{2}$ in. wide, and carried a load of approximately 500 lb. The outer wheel had a slightly crowned steel rim, 3 in. wide, and carried a load of approximately 600 lb. On the front of the truck were mounted two lever mechanisms, *C*. A steel-ball caster, *F*, 1 in. in diam, was attached to one of the levers and exerted a force of 10 lb normal to the track. A swivel steel-wheel caster, 2 in. in diam and $\frac{7}{8}$ in. wide, was attached to the other lever and exerted a force of 20 lb normal to the track. Helical springs, *D*, were used for applying the loads on the casters.

The equipment was propelled around the track in a clockwise direction, at about 2 miles an hour, by a wheel, *G*, 4 ft in diam, which carried a load of approximately 275 lb. The wheel was shod with eight wooden blocks, *H*, 6 by 13 by 1½ in., which were covered with a cushioning layer of rubber ¼ in. thick and a wearing surface of leather ¼ in. thick. This arrangement produced a bumping and slipping action between the wheel and the test floors and imitated, to some extent, a walking action. During the second half of the test, No. 3 grit garnet cloth was placed over the eight leather-surfaced shoes in order to accelerate the abrasive action. The average slippage of the "walking wheel" during the test was approximately 1 percent.

The number of cycles around the track made by the testing equipment was recorded by a counter, *R*, mounted at the side of the track and operated by an arm attached to the truck. A dial depth gage was used to measure the depth of compression and wear caused by the walking wheel and the truck wheels.

A more detailed description of the equipment is given in report BMS34.

III. TEST CONDITIONS AND PROCEDURE

With the exception of one test panel, the concrete subfloors used in this test were the same subfloors used in the first series of tests. The concrete consisted of 1 part of cement, 3 parts of sand, and 4 parts of gravel, with a steel-troweled finish. The surface of the concrete was thoroughly cleaned before installing the second series of floor coverings. With the exception of two test panels, new wood subfloors were installed and consisted of tongued-and-grooved strip flooring, edge-grained Douglas fir, ²⁵⁄₃₂ in. thick, with a 2⅜ in. face. The strip flooring was blind-nailed with 8d cut nails to four wooden sleepers spaced 12 in. on centers. The sleepers were approximately parallel to the direction of travel of the truck and were embedded in concrete.

The floor coverings and adhesives were installed during the latter part of September and early part of October, 1938. Atmospheric conditions in the testing chamber during the installations ranged from 45 to 70 percent in relative humidity and from 65° to 80° F in temperature. A setting-up period of at least two weeks was allowed before starting the test. The performance test covered the period from November 1, 1938 to April 12, 1939. Atmospheric conditions in the testing chamber during the operation of the test truck ranged from 45 to 75 percent in relative humidity and from 30° to 75° F in temperature. The test floors were swept at least once every 500 cycles of the test truck to remove loose particles.

The 40 test installations were subjected to 50 cycles of the testing equipment, after which reference marks of white enamel were placed at intervals on the floor coverings and initial depth measurements were recorded for use in determining the depth of compression and wear made by the equipment. Five measurements were taken of the path made by the walking wheel on each of the 40 installations. Measurements were also taken on a few of the installations of the paths made by the steel-rimmed truck wheel and the rubber-tired truck wheel. These measurements were repeated at 4,000, 10,000, 20,000, 24,000, 30,000, 40,000, and 48,000 cycles of the equipment. During the first 24,000 cycles the eight shoes of the walking wheel were surfaced with strips of leather belting, 6 in. wide. During the second 24,000 cycles the shoes were surfaced with strips of No. 3 grit garnet cloth, 6 in. wide, which were replaced with new strips every 2,000 cycles. After 48,000 cycles of the equipment the test floors were washed with soap and water, and were then photographed.

IV. DESCRIPTION OF TEST INSTALLATIONS

In this second series of tests, five of the installations in the first series were allowed to remain for an additional test. The 35 new installations involved 21 different floor coverings and 12 different adhesives. With a few exceptions, specimens of each floor covering were installed on both a concrete and a wood subfloor. An outline of the test installations is given in table 1.

Table 1.—*Test installations and results of measurements for depth of compression and wear made by the "walking wheel"*

Test panel [a]	Subfloor	Bonding agent	Floor covering		Average depth of depression at—		
			Type and description [b]	Nominal thickness	4,000 cycles	24,000 cycles	48,000 cycles
				Inch	*Inch*	*Inch*	*Inch*
1L	Concrete	Alumina cement-latex adhesive	Battleship linoleum; plain pattern green	1/8	0.000	0.001	0.006
2L	Wood [c]	Lignin paste	do	1/8	.003	.005	.007
1R [d]	Concrete	Oil-base cement, resinous	Battleship linoleum; plain pattern, brown	1/8	.000	.000	.002
2R [d]	Wood	do	do	1/8	.000	.000	.001
3L	Concrete	Casein-latex cement	Sheet rubber; marbleized pattern, brown	1/8	.001	.001	.004
4L	Wood [c]	do	do	1/8	.002	.003	.007
3R	Concrete	Lignin paste	do	1/8	.000	.000	.003
4R	Wood [c]	do	do	1/8	.001	.000	.002
5L	Concrete	Casein-latex cement	Rubber tile,[e] marbleized pattern, gray	1/8	.000	.000	.004
6L	Wood [c]	do	do	1/8	.001	.001	.006
5R	Concrete	Resin cement, copal resin	do	1/8	.000	.000	.007
6R	Wood [c]	do	do	1/8	.001	.001	.016
7L	Concrete	Lignin paste	Composition felt base; jaspe pattern, brown; wearing surface, nitrocellulose composition.	5/64	.001	.001	.005
8L	Wood [f]	do	do	5/64	.003	.005	.012
7R	Concrete	Rubber cement	Mastic felt base; plain pattern, red; wearing surface, pitch, and resin composition.	1/16	.003	.005	.029
8R	Wood [g]	do	do	1/16	.002	.003	.026
9L	Concrete	Cut-back asphalt cement	Mastic felt base; plain pattern, black; wearing surface, asphalt and pitch composition.	5/64	.001	.001	.020
10L	Wood [g]	do	do	5/64	.000	.000	.016
9R	Concrete	do	Mastic felt-base tile;[e] plain pattern, red; wearing surfaec, asphalt and pitch composition.	5/64	.001	.002	.023
10R	Wood [g]	do	do	5/64	.002	.003	.015
11L	Cement mortar [h]	Floor covering as installed	Alumina cement-latex monolithic composition; terrazzo pattern, red; aggregate, marble chips and volcanic ash; density, 120 lb./ft.^{3}; crushing strength, 1,600 lb./in.^{2}	1/4	.006	.008	.063
11R	do [h], [i]	do	Magnesium oxychloride monolithic composition; plain pattern, green; aggregate, marble dust, cotton fiber and copper powder; density, 108 lb./ft.^{3}; crushing strength, 5,700 lb./in.^{2}	1/4	.001	.001	.019
12L	Concrete [j]	do	Magnesium-oxychloride monolithic composition; plain pattern, red; aggregate, calcite; density, 108 lb./ft.^{3}; crushing strength, 7,400 lb./in.^{2}	3/4	.001	.001	.017
12R [d]	do	Cut-back asphalt cement	Short-strip maple; equal-length shorts	25/32	.001	.001	.006
13R [d]	do	Oil-base cement, resinous	Pressed fiberboard; plain pattern, brown	1/8	.000	.001	.033
14R [d]	Wood	Nailed, 2d casing nail	do	1/8	.003	.003	.030
13L	Concrete [k]	Cut-back asphalt cement	Asphalt tile; [e] plain pattern, red; 1-minute indentation, 0.007 in.[l]	3/16	.000	.001	.026
14L	Wood [c]	Asphalt emulsion, soap type	Asphalt tile; [e] marbleized pattern, white; 1-minute indentation, 0.006 in.[l]	1/8	.003	.004	.024
15L	Concrete [k]	Cut-back asphalt cement	Asphalt tile; [e] plain pattern, white; cumar-resin type; 1-minute indentation, 0.010 in.[l]	3/16	.001	.001	.017
16L	Wood [c]	Asphalt emulsion, clay type	do	3/16	.002	[m].004	.019
15R	Concrete [k]	Cut-back asphalt cement	Asphalt tile; [e] plain pattern, mahogany; asphalt type; 1-minute indentation, 0.010 in.[l]	3/16	.000	.000	.022
16R	Wood [c]	Asphalt emulsion, clay type	do	3/16	.003	.005	.023
17L	Concrete [k]	Cut-back asphalt cement	Asphalt tile; [e] plain pattern, white; cumar-resin type; 1-minute indentation, 0.008 in.[l]	1/8	.001	.001	.014
18L	Wood [c]	Asphalt emulsion, clay type	do	1/8	.002	.002	.016
17R	Concrete [k]	Cut-back asphalt cement	Asphalt tile;[e] plain pattern, mahogany; asphalt type; 1-minute indentation, 0.009 in.[l]	1/8	.001	.001	.022
18R	Wood[c]	Asphalt emulsion, clay type	do	1/8	.002	.002	.018
19L	Concrete [k]	Asphalt emulsion, soap type	Asphalt tile;[e] plain pattern, maroon; contained scrap asphalt-roofing material; 1-minute indentation, 0.011 in.[l]	1/8	.000	.000	.012
20L	Wood [n]	do	do	1/8	.000	.002	.018
19R	Concrete [k]	do	Asphalt tile;[e] plain pattern, black; 1-minute indentation, 0.010 in.[l]	1/8	.001	.001	.023
20R	Wood [c]	do	do	1/8	.001	.001	.019

[a] *L*, left half of panel; *R*, right half of panel (facing the panels from the inside of the circular track).
[b] Color listed is the predominating color.
[c] Underlay of 1½ lb./yd.^{2} asphalt-saturated lining felt bonded to subfloor with lignin paste.
[d] Remaining from first series of tests. See report BMS34 for details of installation and results of first test.
[e] Size of tile, 9 by 9 in.
[f] Underlay of ¾ lb./yd.^{2} dry lining felt bonded to subfloor with lignin paste.
[g] No underlay of lining felt.
[h] Mortar fill of 1 part of cement and 2 parts of sand, ½ in. thick, over concrete and sleepers. Surface given a wood-float finish.
[i] Subfloor given a priming coat of cut-back resin varnish.
[j] Steel-troweled surface of subfloor thoroughly chipped and primed with magnesium-chloride solution.
[k] Subfloor given a priming coat of cut-back asphalt primer.
[l] Method prescribed in Federal Specification SS-T-306, Tile; Asphalt.
[m] Result of 10,000 cycles reported, due to warped condition of tiles at 24,000 cycles.
[n] Underlay of 1½ lb./yd.^{2} asphalt-saturated lining felt bonded to subfloor with adhesive listed.

V. RESULTS

The depth of the depressions in the floor coverings made by the walking wheel at 4,000, 24,000, and 48,000 cycles are recorded in table 1. In general, for the first 24,000 cycles the walking wheel, surfaced with leather, caused very little wear. The depressions appeared to result principally from compression and occurred mainly within the first 4,000 cycles. For most of the floor coverings the depressions were greater on a wood subfloor than on a concrete subfloor, especially where an underlay of lining felt was used on the wood subfloor. Between 24,000 and 48,000 cycles the walking wheel surfaced with abrasive cloth caused measurable amounts of wear on the floor coverings. The average wear of the different floor coverings during this period is shown in table 2. The averages were computed from the difference in the results given in table 1 for depth of compression and wear at 24,000 and 48,000 cycles.

Table 2.—*Average wear of floor coverings caused by 24,000 cycles of the "walking wheel" surfaced with abrasive cloth* [a]

Floor covering [b]	Average depth of wear
	Inch
Battleship linoleum, green	0.004
Battleship linoleum, brown [c]	.002
Sheet rubber, brown	.003
Rubber tile, gray	.008
Composition felt base, brown	.006
Mastic felt base, red	.024
Mastic felt base, black	.018
Mastic felt-base tile, red	.017
Cement-latex composition, red	.055
Magnesium-oxychloride composition, green	.018
Magnesium-oxychloride composition, red	.016
Short-strip maple [c]	.005
Pressed fiberboard [c]	.030
Asphalt tile, 3/16 in., red	.025
Asphalt tile, 1/8 in., marbleized white	.020
Asphalt tile, 3/16 in., white	.016
Asphalt tile, 3/16 in., mahogany	.020
Asphalt tile, 1/8 in., white	.014
Asphalt tile, 1/8 in., mahogany	.019
Asphalt tile, 1/8 in., maroon	.014
Asphalt tile, 1/8 in., black	.020

[a] The relative value of a floor covering should not be based entirely on resistance to wear. Other factors should also be considered, such as cost, indentation characteristics, ease of maintenance, adherence to subfloors, resistance to tear and fracture.

[b] See table 1 for detailed description.

[c] Additional test on first series of installations. See report BMS34 for results of first test.

One very evident fact in this test was the ability of the floor coverings and bonding agents as a whole to withstand the action of the rubber-tired truck wheel in comparison to the damage done by the steel-tired truck wheel to many of them. With the exception of some of the asphalt tile installed on a wood subfloor, the rubber-tired truck wheel caused very little fracture of the floor coverings or failure in the bonding agents. The steel-tired truck wheel caused failures ranging from a few small blisters and fractures in some of the floor coverings to a complete crushing or tearing of others.

In view of the severe action of the steel-tired truck wheel on both the floor covering and the bonding agent and the probability of uncertain or erroneous results due to failure in the bond and to buckling of the floor coverings, measurements of the depressions caused by the truck wheels were limited to the monolithic floors and a few others for comparative purposes. These results are recorded in table 3.

Table 3.—*Depth of compression and wear made by truck wheels*

Test panel	Subfloor	Floor covering	Average depth of depression			
			Rubber-tired wheel		Steel-tired wheel	
			10,000 cycles	48,000 cycles	10,000 cycles	48,000 cycles
			Inch	*Inch*	*Inch*	*Inch*
1L	Concrete	Battleship linoleum, green.	0.000	0.000	0.001	0.004
1R	do	Battleship linoleum, brown. [a]	.001	.001	.000	.003
11L	Cement mortar.	Alumina cement-latex composition, red.	.003	.003	.023	.044
11R	do	Magnesium-oxychloride composition, green.	.001	.002	.001	.011
12L	Concrete	Magnesium-oxychloride composition, red.	.000	.000	.002	.018
12R	do	Short-strip maple [a]	.000	.002	.001	.011

[a] Additional test on first series of installations. See report BMS34 for results of first test.

With a few exceptions, the ball and roller casters caused very little compression or wear in the floor coverings.

The accompanying photographs, figures 2 to 34, show the general condition of representative installations of the different floor coverings at the end of 48,000 cycles of the testing equipment. With the exceptions of figures 6 and 9, the paths shown in the photographs are, from left to right, those made by the rubber-tired truck wheel, the steel-ball caster, the walking wheel, the steel-wheel caster, and the steel-tired truck wheel. The small white dots in the photographs are reference marks of white enamel used in taking the depth measurements.

The floor coverings shown in figures 35, 36, and 37 were exposed to both series of tests, a total of 96,000 cycles of the equipment.

Brief summaries of the manner in which the various test installations performed are herewith presented:

The ⅛-in. green battleship linoleum, test panels *1L* and *2L*, showed very good performance (see figs. 2 and 3, and table 2). There was no evidence of failure in adhesion to the subfloors. On a wood subfloor, panel *2L*, the linoleum was fractured slightly at one end by the steel-tired truck wheel (see fig. 3). On a concrete subfloor the linoleum was only slightly indented by the steel-tired truck wheel (see table 3).

The ⅛-in. sheet rubber, test panels *3L*, *4L*, *3R*, and *4R*, gave excellent performance (see figs. 4 and 5, and table 2). No failure occurred in adhesion to the subfloors except in panel *3L*, where the casein-latex adhesive accumulated in rolls along the path of the steel-tired truck wheel, causing welts to form in the floor covering (see fig. 6). There was no evidence of fracture of the sheet rubber.

The ⅛-in. rubber tile on a wood subfloor, test panels *6L* and *6R*, showed very good performance (see fig. 8), with no evidence of failure in adhesion to the subfloor or fracture of the rubber tile. On a concrete subfloor, test panels *5L* and *5R*, considerable failure in adhesion to the subfloor and fracture of the tile along the path of the steel-tired truck wheel were observed (see figs. 7 and 9). In test panel *5L* there were also welts in the floor covering, caused by accumulations of the casein-latex adhesive (see fig. 9). The rubber tile was worn to a moderate degree by the abrasive action of the walking wheel (see table 2).

The nitrocellulose composition felt base, test panels *7L* and *8L*, withstood the severe test very well (see figs. 10 and 11). The only failure in adhesion to the subfloors was a few small blisters along the path of the steel-tired truck wheel in panel *7L* (see fig. 10). On a wood subfloor with a dry lining felt the floor covering was moderately depressed and the wearing surface was fractured slightly by the steel-tired truck wheel (see fig. 11). Upon removal of the test panel there was evidence of some separation in the dry lining felt along the path of the steel-tired truck wheel. The wearing surface was not worn through to the asphalt-saturated felt backing by the abrasive action of the walking wheel (see table 2). In general, the floor covering was still in serviceable condition at the end of the test.

The pitch and resin mastic felt base,[2] test panels *7R* and *8R*, showed very poor performance (see figs. 12 and 13). The wearing surface was crumbled and completely worn through to the felt backing along the paths of the steel-tired truck wheel and the steel-wheel caster. The wearing surface was also worn through in spots by the abrasive action of the walking wheel in 1,700 cycles after the wheel had been covered with abrasive cloth, and was worn through over the entire path in 6,000 cycles. The total depth of wear is shown in table 2. The only failure in adhesion to the subfloors occurred as blisters along the path of the steel-tired truck wheel in panel *7R* (see fig. 12). This failure, however, did not occur until after 43,000 cycles of the truck, by which time the surface of the floor covering was completely worn through to the felt backing.

The asphalt and pitch mastic felt base floor coverings, in sheet and tile form, test panels *9L*, *10L*, *9R*, and *10R*, were in unserviceable condition at the end of the performance test. On a concrete subfloor the floor coverings were considerably pitted and the bond broken along the path of the steel-tired truck wheel (see figs. 14 and 16). On a wood subfloor considerable failure in bond and fracture of the floor coverings along the path of the steel-tired truck wheel occurred (see figs. 15 and 17). This was especially so for the tile, which curled up at the corners and edges and were displaced. Some of the tile were recemented and later replaced in order to continue the test. The wearing surface of the floor coverings was worn through in spots by the abrasive action of the walking wheel in 7,800 cycles after the wheel had been covered with abrasive cloth. The total depth of wear is shown in table 2. The floor coverings were also worn to a moderate degree by the steel-wheel caster.

---

[2] The authors have been informed by the manufacturer that, as a result of failures also in service, the merchandise represented by this sample has been removed from the market.

The ¼-in. alumina cement-latex monolithic floor, test panel *11L*, was considerably depressed by the steel-tired truck wheel (see table 3). There was also evidence of some pitting and wear (see fig. 18). The floor was worn to a considerable degree by the abrasive action of the walking wheel (see table 2). There was no evidence of the floor cracking, even though it was installed over a cement-mortar fill only ½ in. thick.

The ¼-in. magnesium-oxychloride monolithic floor, test panel *11R*, was pitted and worn to a moderate degree by the steel-tired truck wheel (see fig. 19 and table 3). The floor was worn to an appreciable degree by the abrasive action of the walking wheel (see table 2). The cotton fibers showed as fuzz along the paths of the steel-tired truck wheel and the walking wheel (see fig. 19). Inasmuch as the subfloor consisted of a ½-in. cement-mortar fill and not a solid concrete slab, it is not considered advisable to place too much significance on the cracks which appeared along the path of the steel-tired truck wheel and across the paths of the walking wheel and the steel-wheel caster (see fig. 19). Upon removal of the test panel the ½-in. cement-mortar fill was also found to be cracked along the path of the steel-tired truck wheel. However, it was found possible to separate easily and completely the ¼-in. magnesium-oxychloride layer from the ½-in. cement-mortar fill, which would indicate a poor bond for this type of material.

The ¾-in. magnesium-oxychloride monolithic floor, test panel *12L*, was pitted and worn to a moderate degree by the steel-tired truck wheel (see fig. 20 and table 3). The floor was worn to an appreciable degree by the abrasive action of the walking wheel (see table 2). There was no evidence of the floor cracking. Upon removal of the test panel, bond to the chipped concrete subfloor was found to be very good.

The ⅛-in. and $^3\!/_{16}$-in. asphalt tiles, in general, did not stand up well in this test (see figs. 21 to 34 and table 2). With the exception of panels *15L* and *15R*, the tiles were badly broken and crushed by the steel-tired truck wheel. The tiles in panels *15L* and *15R* were pitted and worn to a moderate degree (see figs. 23 and 25). All the tiles were appreciably worn by the abrasive action of the walking wheel (see table 2). On a wood subfloor the tiles were also fractured to a considerable degree by the walking wheel (see figs. 22, 24, 26, 28, 30, 32, and 34). The tiles in panels 15, 16, 17, and 18 showed a tendency to curl. On a wood subfloor with the clay type of asphalt emulsion, panels 16 and 18, there was evidence of considerable failure in bond and the tiles were fractured by the rubber-tired truck wheel (see figs. 24, 26, 28, and 30). In general, the asphalt tiles showed better performance over a concrete subfloor than over a wood subfloor, and the results indicate that complete contact with a firm and even subfloor is essential to prevent the tile from cracking under traffic.

The following installations were carried over from the first series of tests and were thus exposed to a total of 96,000 cycles of the testing equipment.

The ⅛-in. brown battleship linoleum, test panels *1R* and *2R*, was in good condition after exposure to the additional test (see fig. 35 and tables 2 and 3). Along the path of the steel-tired truck wheel there was some failure in adhesion to the concrete subfloor in panel *1R* and slight fracture of the linoleum at one end of panel *2R*.

The short-strip maple flooring, test panel *12R*, was in good condition after exposure to the additional test except for some failure in adhesion to the concrete subfloor (see fig. 36 and tables 2 and 3). The adhesion failure was indicated by the presence of slight separations in some of the end joints (see fig. 36) and by the hollow sound produced by many of the strips when tapped on the surface with a hard object. Failure in bond was further verified by the condition of the adhesive when the test panel was removed. Contact of the test floor with the concrete subfloor appeared to be about 50 percent.

The ⅛-in. pressed fiberboard, test panels *13R* and *14R*, was in unsatisfactory condition for additional service due to the total depth of wear caused by the abrasive action of the walking wheel during both series of tests (see fig. 37 and table 2). Bond to the subfloors was not complete, as determined by the chatter of the

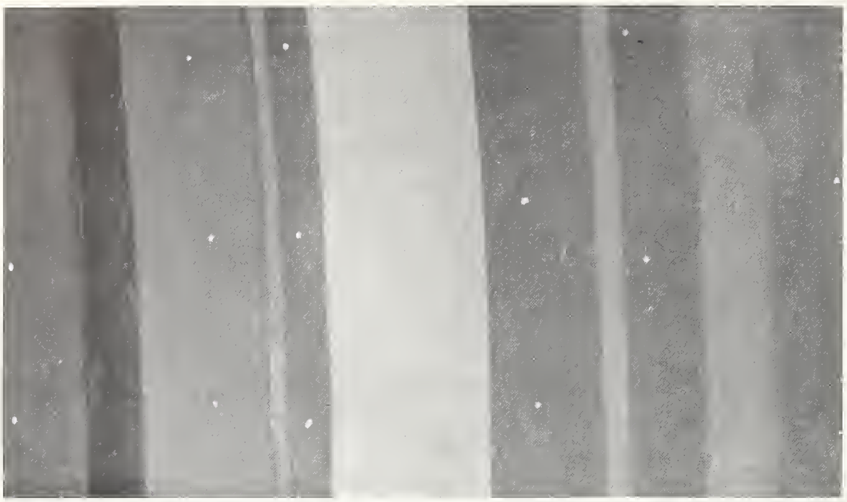


Figure 2.—*⅛-in. battleship linoleum on concrete subfloor (test panel 1L).*

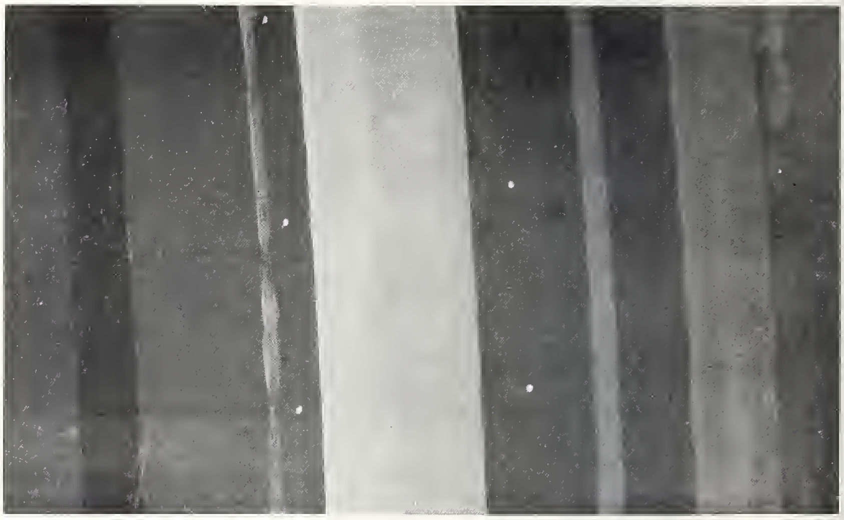


Figure 3.—*⅛-in. battleship linoleum on wood subfloor (test panel 2L).*

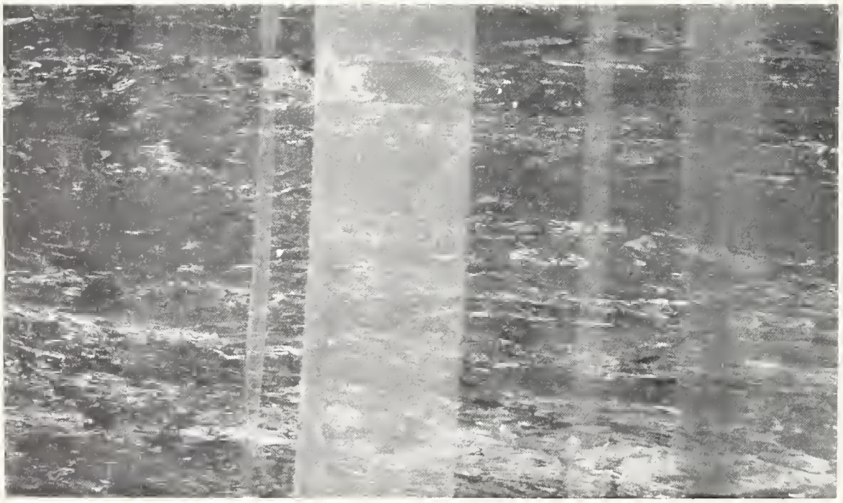


Figure 4.—*⅛-in. sheet rubber on concrete subfloor (test panel 3R).*

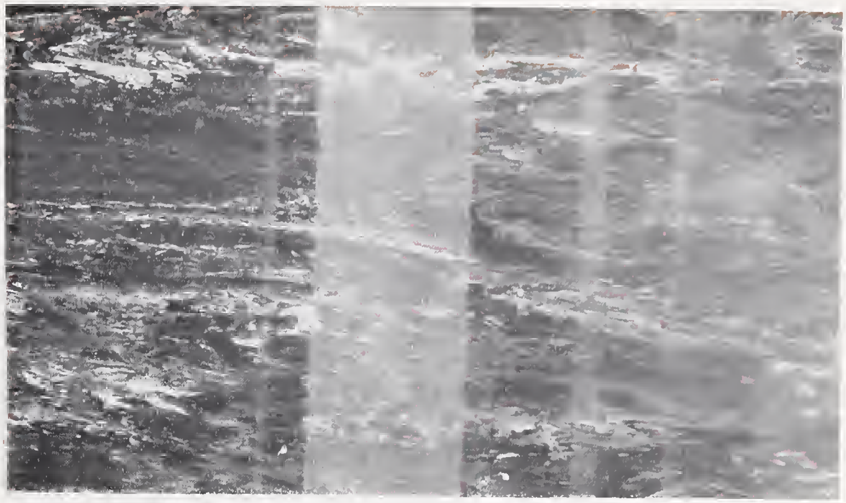


FIGURE 5.—⅛-in. sheet rubber on wood subfloor (test panel 4R).

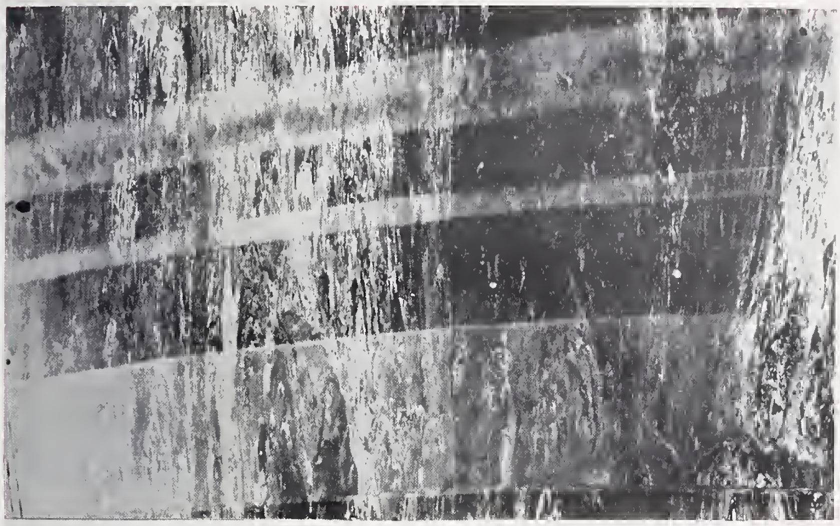


FIGURE 6.—⅛-in. sheet rubber on concrete subfloor (test panel 3L).

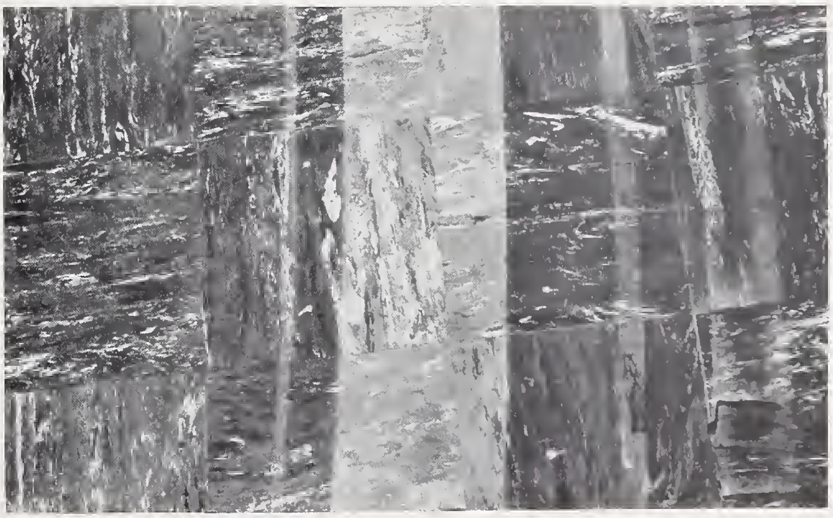


FIGURE 7.—⅛-in. rubber tile on concrete subfloor (test panel 5R).

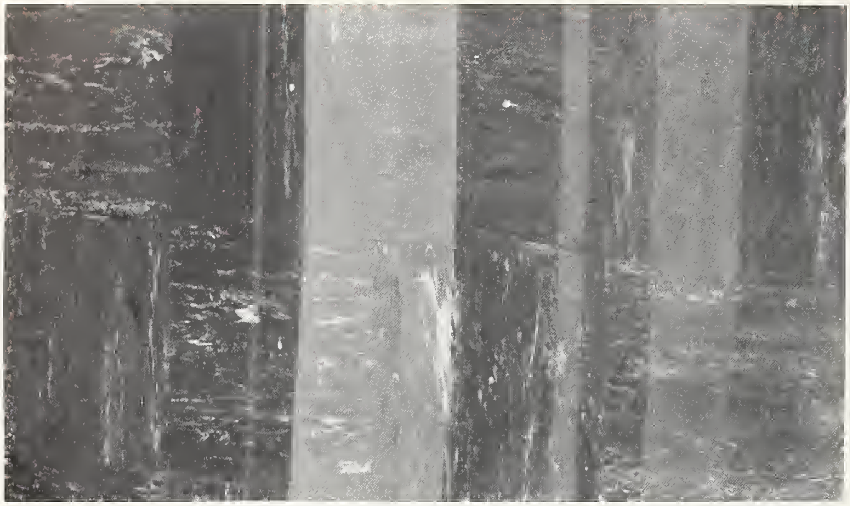


FIGURE 8.—⅛-*in. rubber tile on wood subfloor (test panel 9R).*

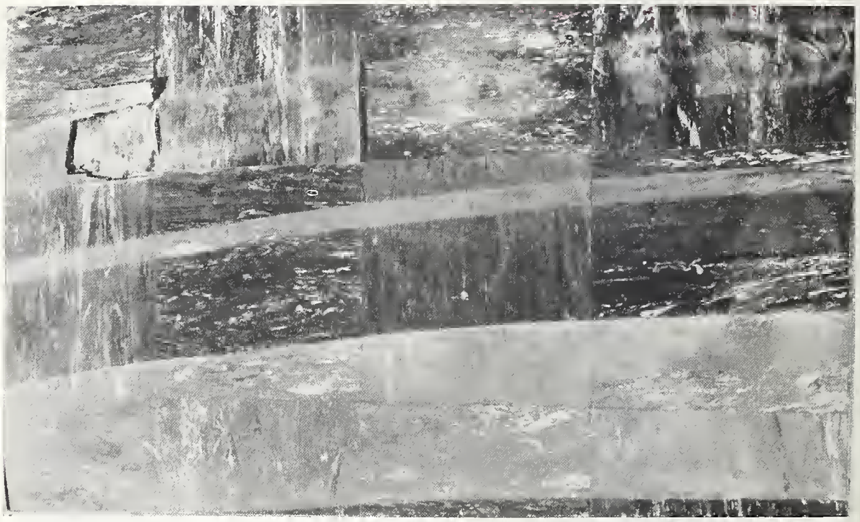


FIGURE 9.—⅛-*in. rubber tile on concrete subfloor (test panel 5L).*

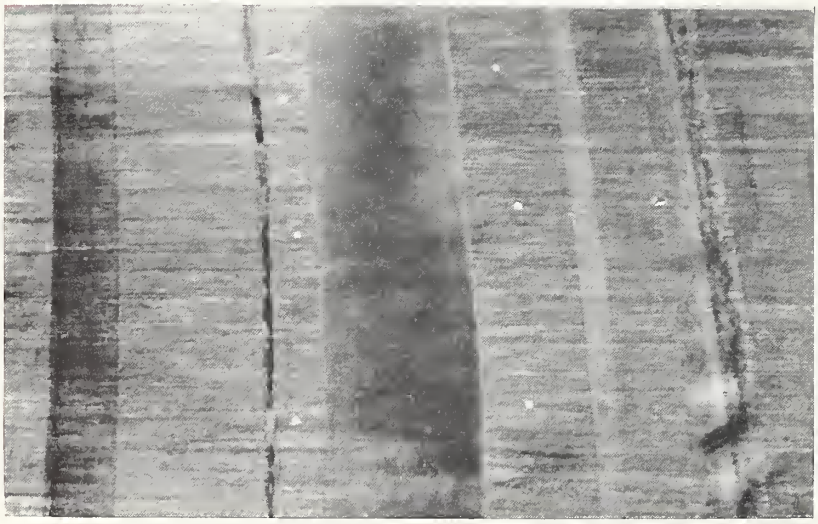


FIGURE 10.—*Nitrocellulose composition felt base on concrete subfloor (test panel 7L).*

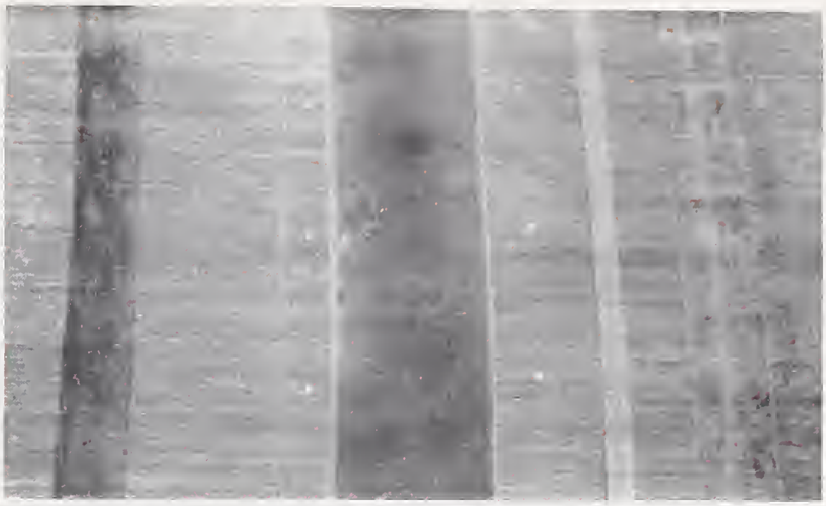


Figure 11.—*Nitrocellulose composition felt base on wood subfloor (test panel 8L).*

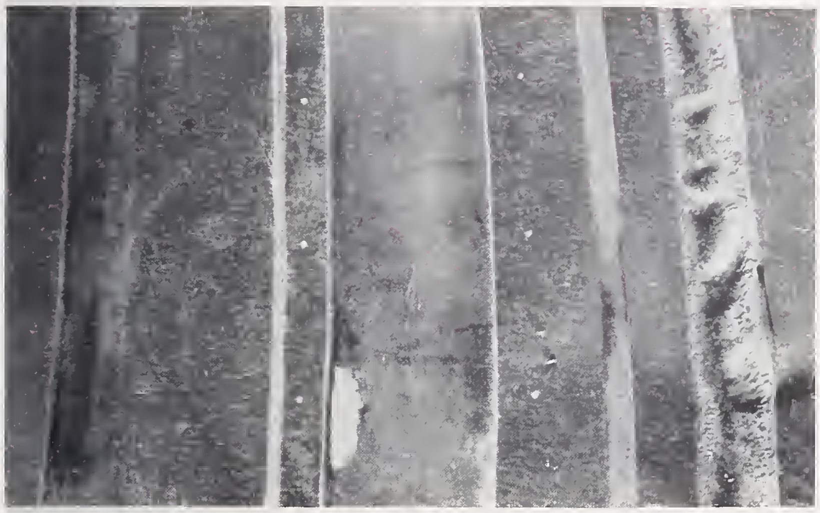


Figure 12.—*Pitch and resin mastic felt base on concrete subfloor (test panel 7R).*

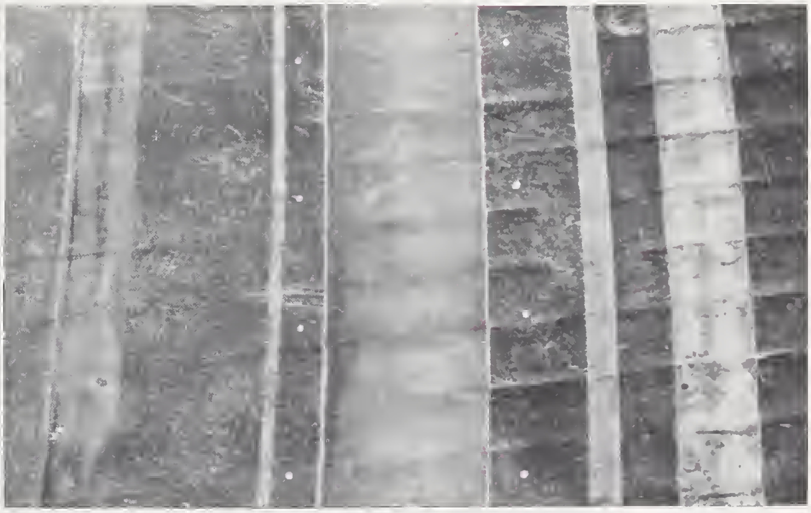


Figure 13.—*Pitch and resin mastic felt base on wood subfloor (test panel 8R).*

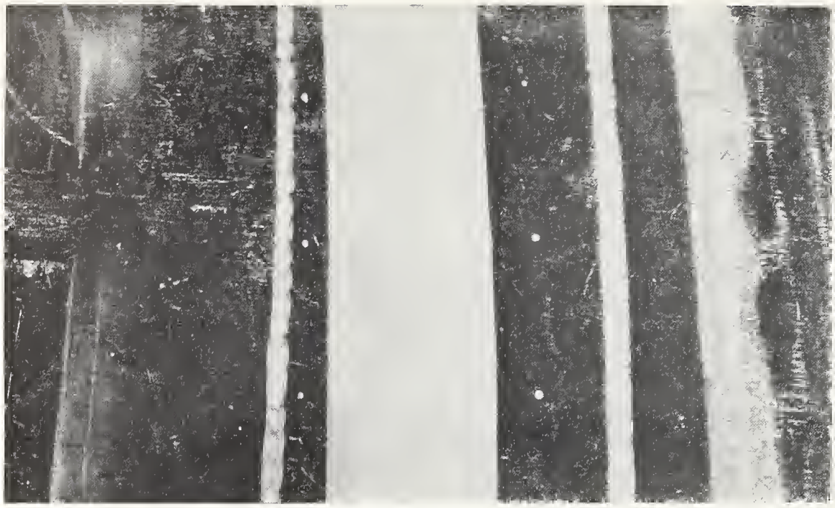
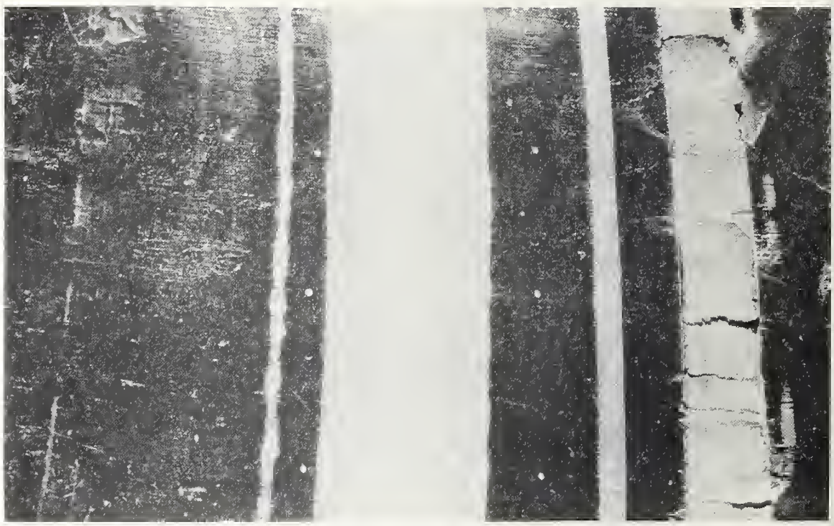


Figure 14.—*Asphalt and pitch mastic felt base on concrete subfloor (test panel 9L).*

Figure 15.—*Asphalt and pitch mastic felt base on wood subfloor (test panel 10L).*



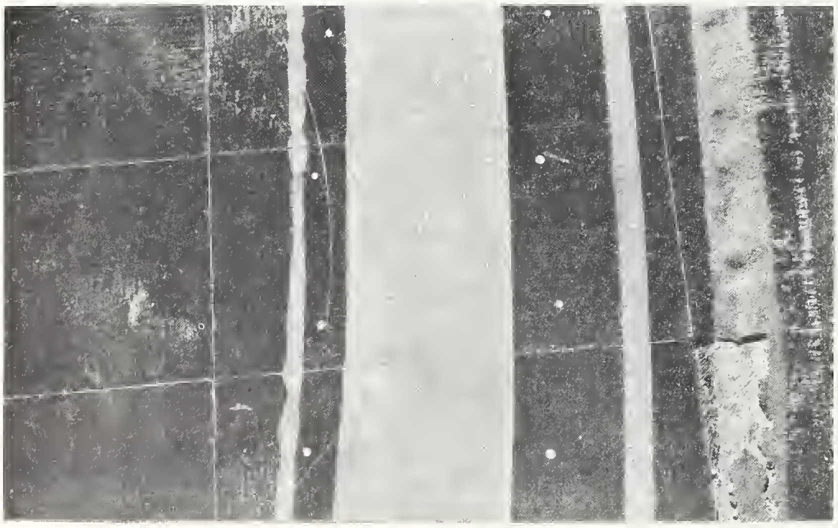


Figure 16.—*Asphalt and pitch mastic felt-base tile on concrete subfloor (test panel 9R).*

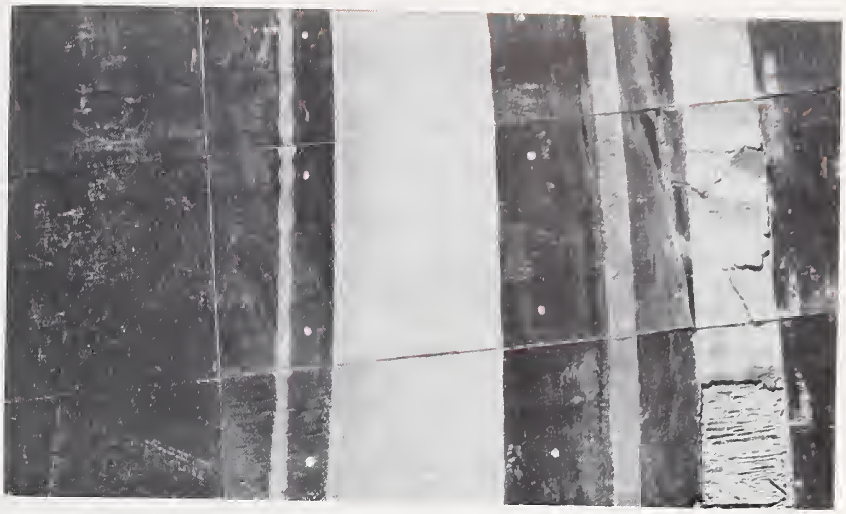


Figure 17.—*Asphalt and pitch mastic felt-base tile on wood subfloor (test panel 10R).*

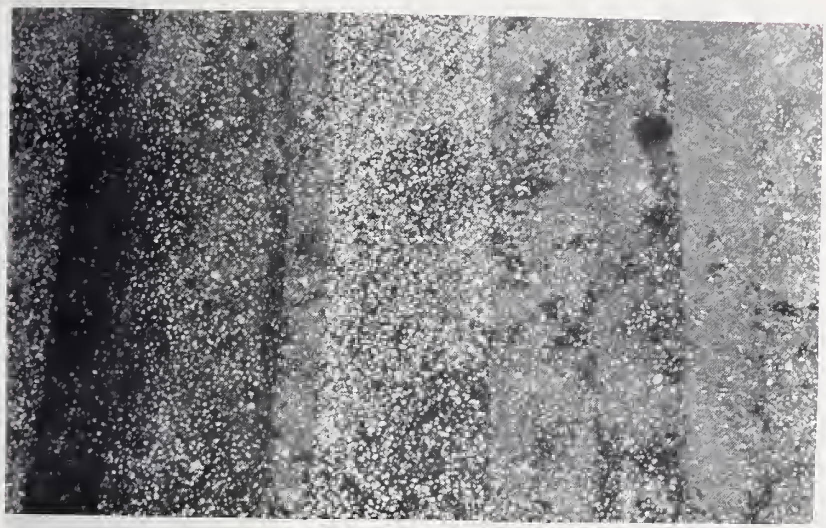


Figure 18.—*¼-in. alumina cement-latex monolithic composition on cement-mortar subfloor (test panel 11L).*

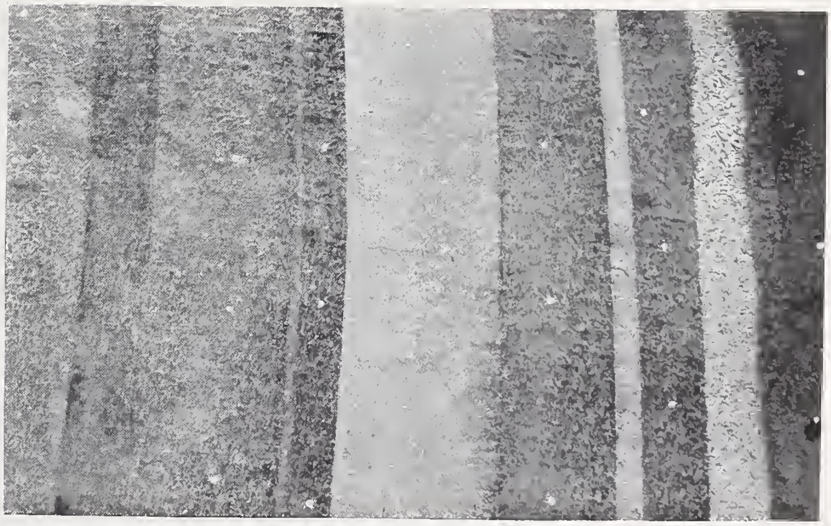


Figure 19.—*¼-in. magnesium-oxychloride monolithic composition on cement-mortar subfloor (test panel 11R).*

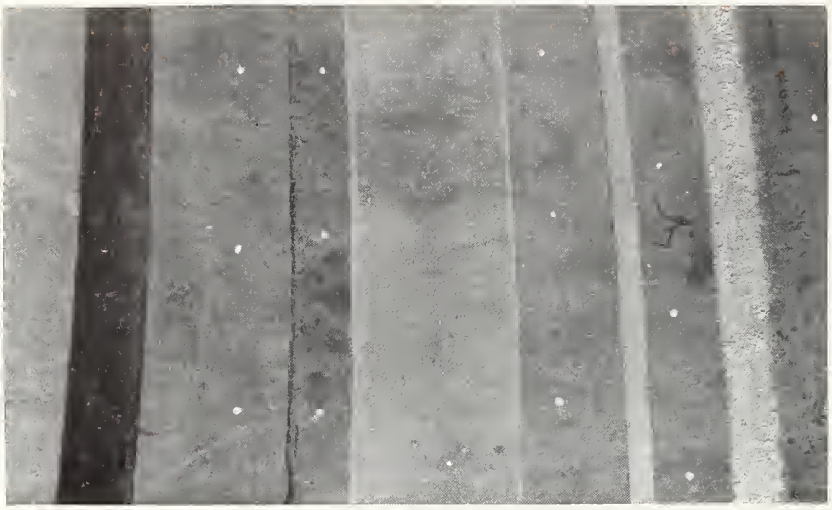


FIGURE 20.—¾-*in. magnesium-oxychloride monolithic composition on concrete subfloor (test panel 12L).*

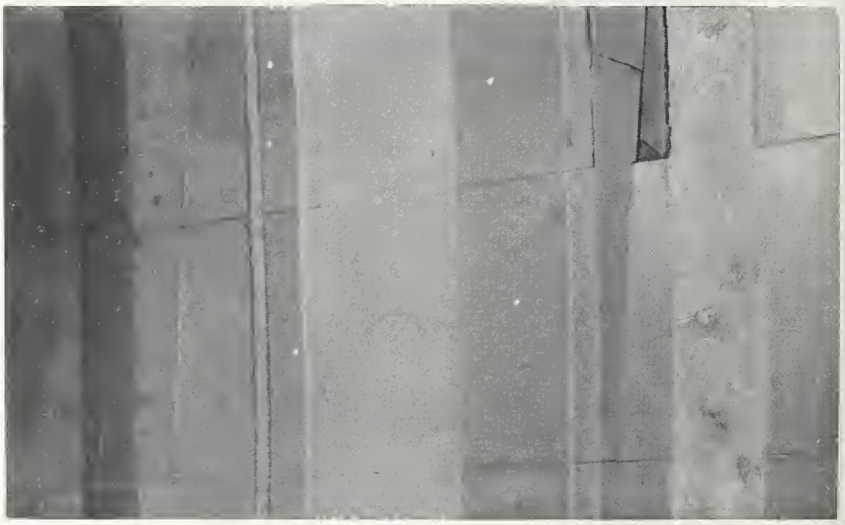


FIGURE 21.—$^3/_{16}$-*in. asphalt tile on concrete subfloor (test panel 13L).*

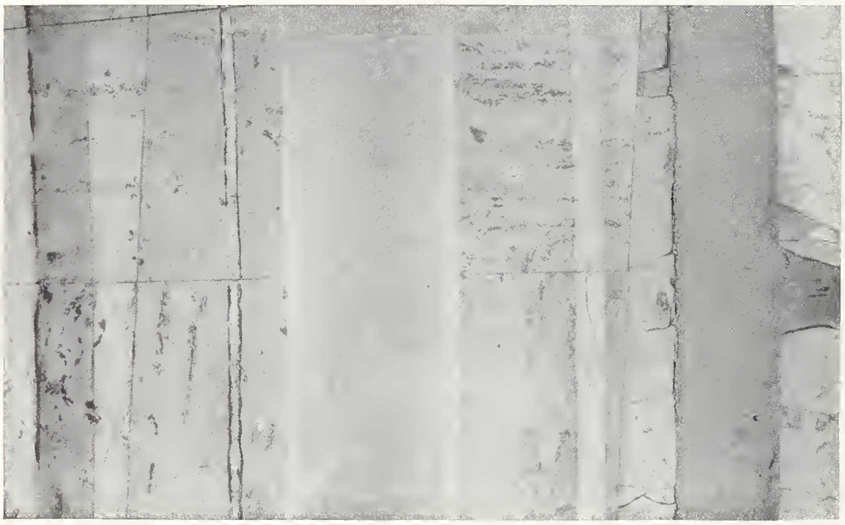


FIGURE 22.—⅛-*in. asphalt tile on wood subfloor (test panel 14L).*

Figure 23.—$^3/_{16}$-*in. asphalt tile, cumar-resin type, on concrete subfloor (test panel 15L).*

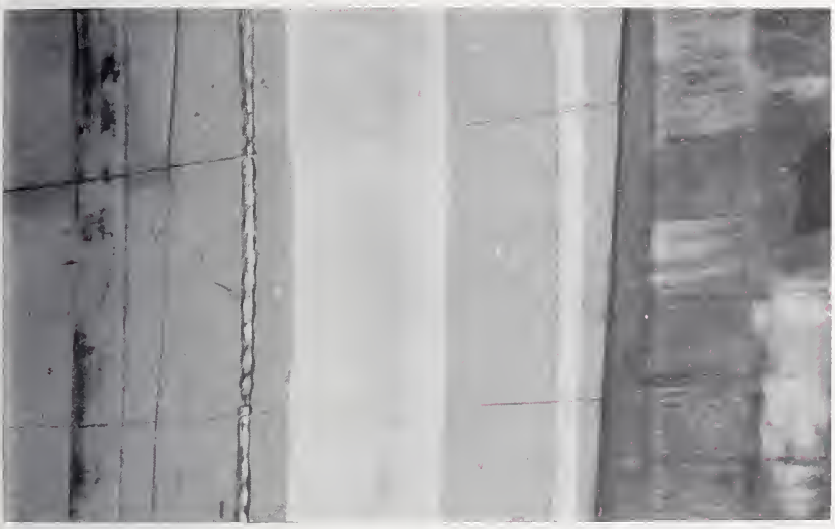


Figure 24.—$^3/_{16}$-*in. asphalt tile, cumar-resin type, on wood subfloor (test panel 16L).*

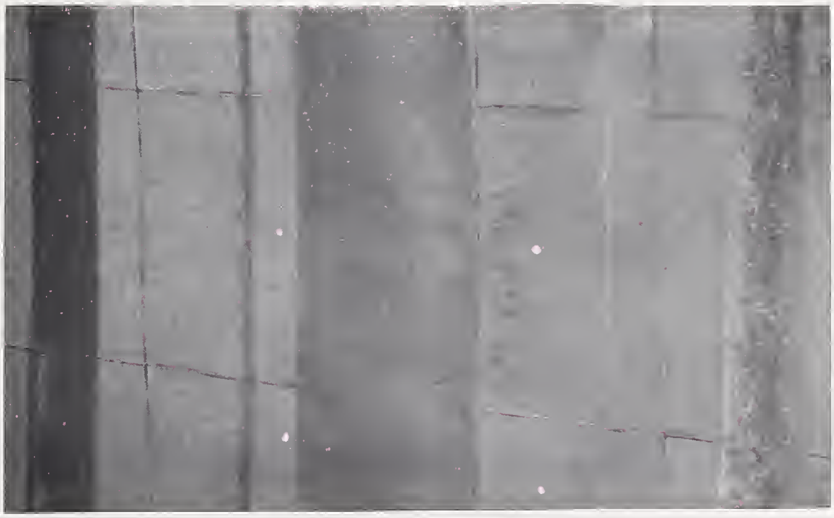


Figure 25.—$^3/_{16}$-*in. asphalt tile, asphalt type, on concrete subfloor (test panel 15R).*

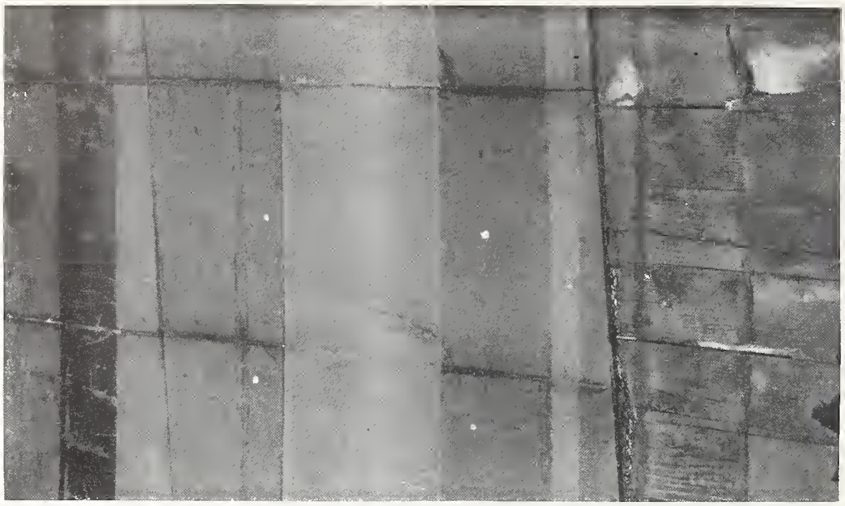


FIGURE 26.—$^3/_{16}$-*in. asphalt tile, asphalt type, on wood subfloor (test panel 16R).*

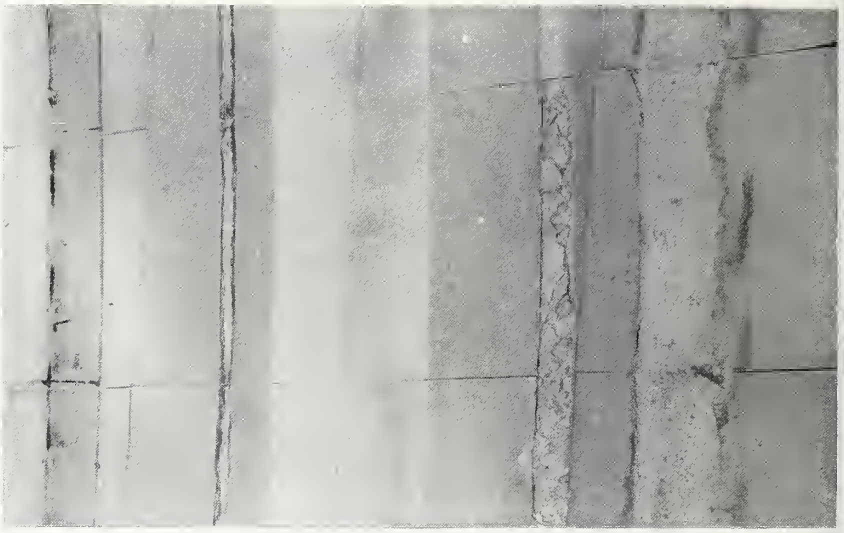


FIGURE 27.—$^1/_8$-*in. asphalt tile, cumar-resin type, on concrete subfloor (test panel 17L).*

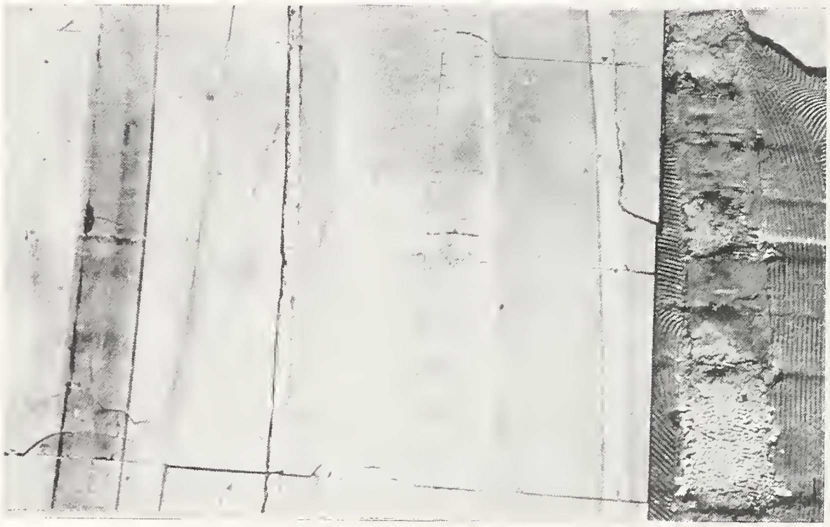


FIGURE 28.—$^1/_8$-*in. asphalt tile, cumar-resin type, on wood subfloor (test panel 18L).*

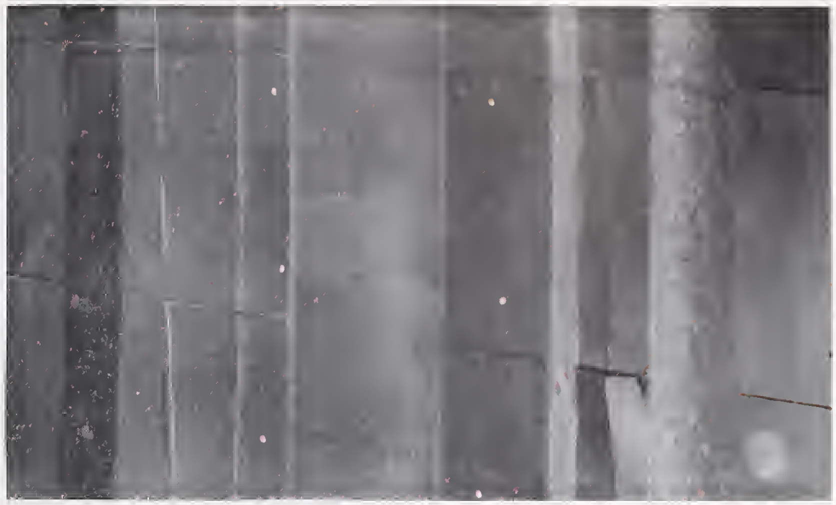


FIGURE 29.—⅛-in. asphalt tile, asphalt type, on concrete subfloor (test panel 17R).

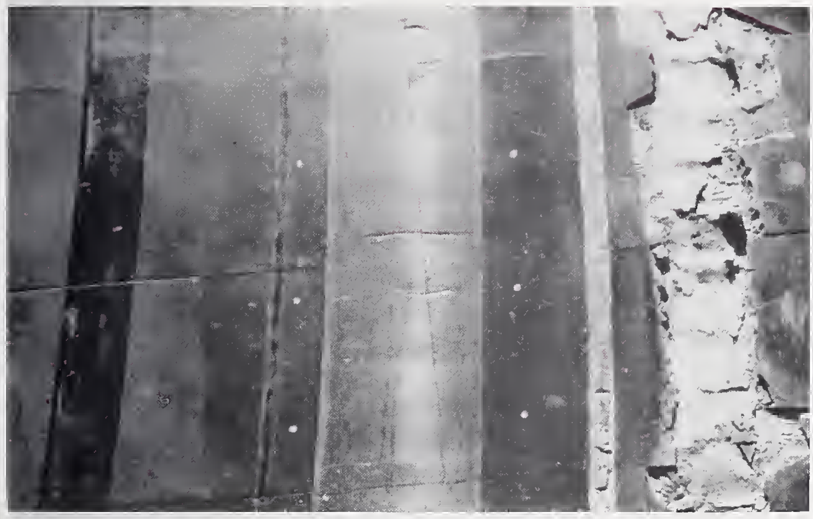


FIGURE 30.—⅛-in. asphalt tile, asphalt type, on wood subfloor (test panel 18R).

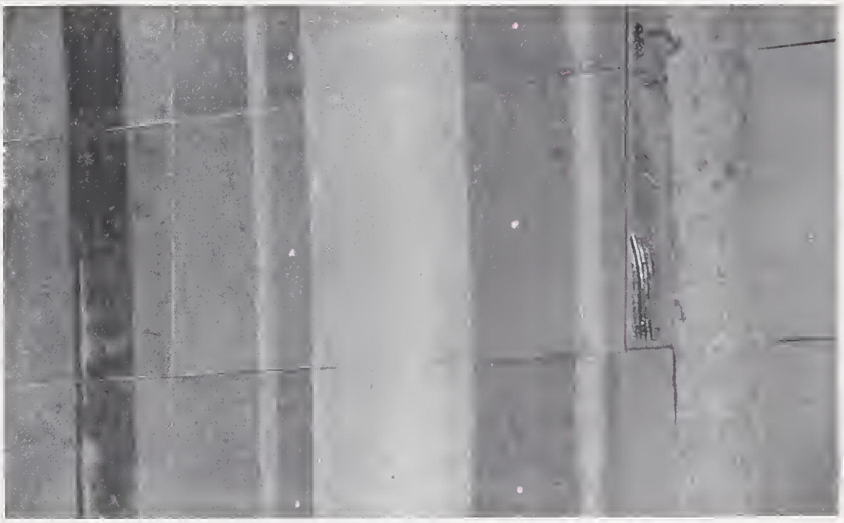


FIGURE 31.—⅛-in. asphalt tile, containing asphalt roofing material, on a concrete subfloor (test panel 19L).

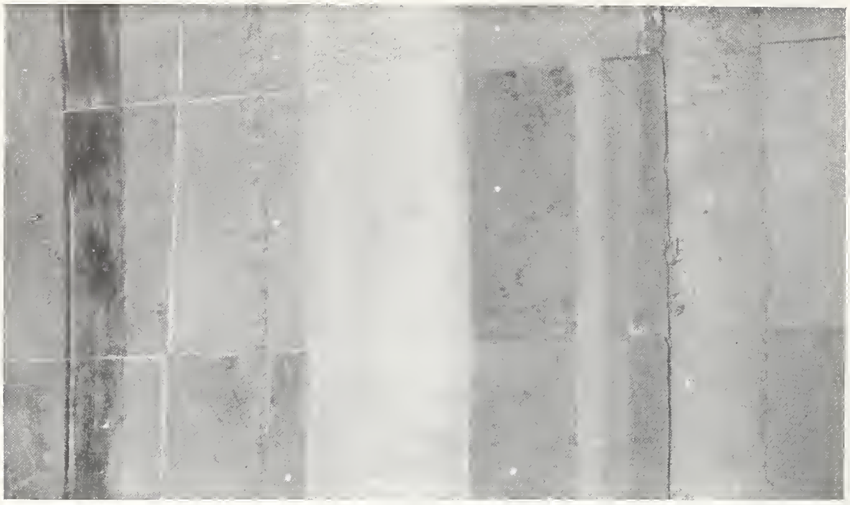


Figure 32.—⅛-in. asphalt tile, containing asphalt roofing material, on a wood subfloor (test panel 20L).

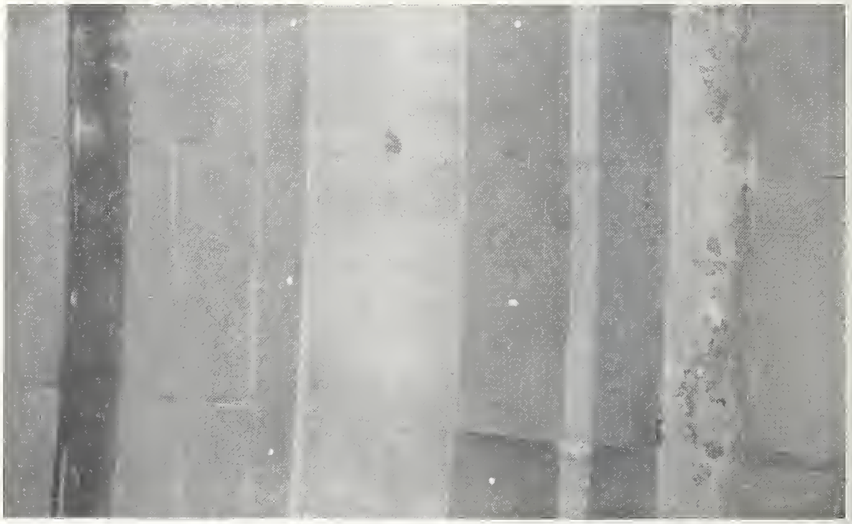


Figure 33.—⅛-in. asphalt tile on concrete subfloor (test panel 19R).

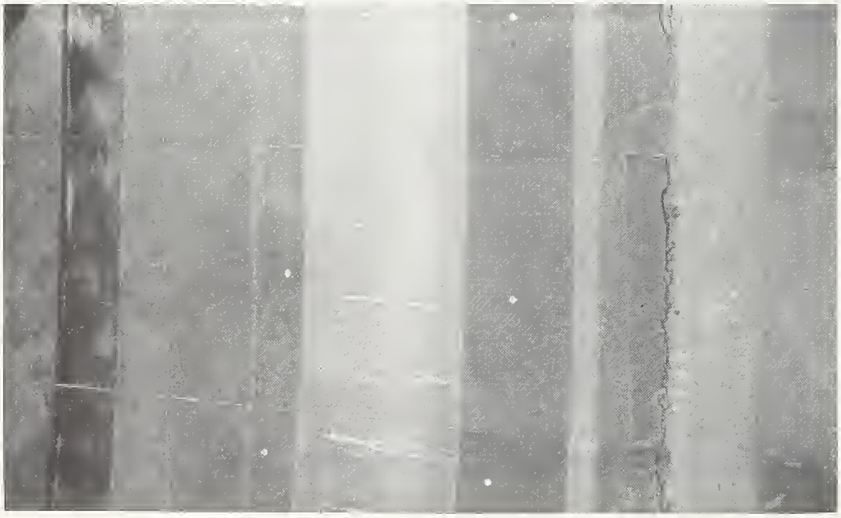


Figure 34.—⅛-in. asphalt tile on wood subfloor (test panel 20R).

FIGURE 35.—⅛-in. *battleship linoleum on concrete subfloor (test panel 1R).*

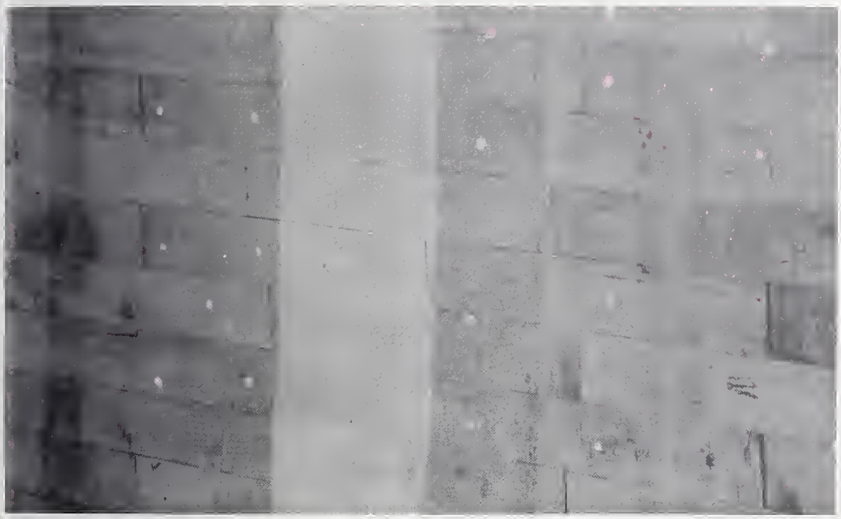


FIGURE 36.—²⁵⁄₃₂-in. *short-strip maple on concrete subfloor (test panel 12R).*

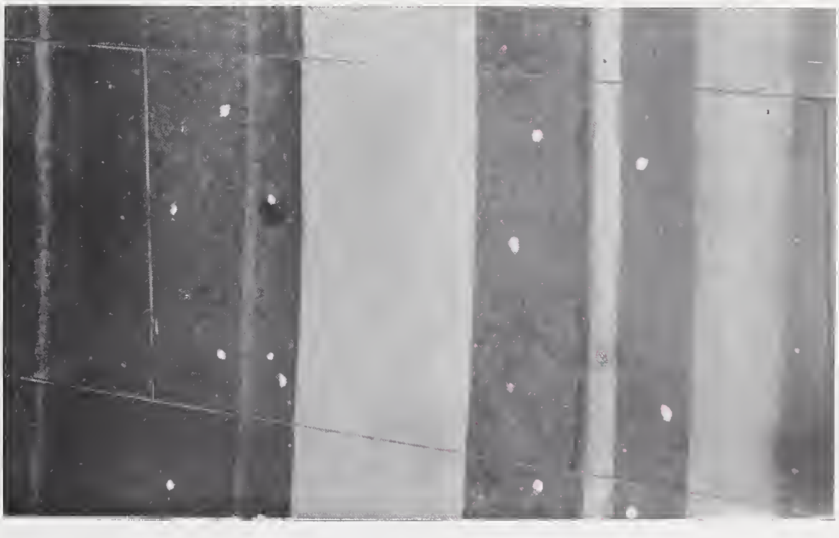


FIGURE 37.—⅛-in. *pressed fiberboard on wood subfloor (test panel 14R).*

fiberboards when tapped. On a wood subfloor fractures and separations in the fiberboard were observed along the path of the steel-tired truck wheel (see fig. 37). In panel *14R* some of the nail heads were protruding to a slight degree.

VI. COMMENTS

In the selection and installation of a floor covering it is advisable to follow the recommendations of a reputable manufacturer or installer. Important factors to be considered are: Condition of the subfloor as to evenness, cleanliness, and rigidity; exposure to which the installation will be subjected, especially with respect to moisture, concentrated loads, and traffic; durability in relation to cost; and ease or cost of removal and replacement.

In interpreting the results of this performance test as an aid in the selection of a floor covering and a method of installation, it should be borne in mind that the test is highly accelerated and represents very severe service. In view of this fact, some of the lower-cost floor coverings, even though less durable, may render economical and satisfactory service provided that they are not subjected to abuse and that only moderate length of service is required. They may render more service per unit of total cost (initial and maintenance or renewal) than some of the floor coverings of higher initial cost.

In general, the results show that battleship linoleum, rubber, maple, and nitrocellulose composition felt base are durable floor coverings even under severe service; but it should not be concluded that the other floor coverings are not to be considered, as they may render satisfactory service under less severe exposure and may possess specific properties essential to meet certain conditions.

The advisability of using dry lining felt in conjunction with felt-base floor coverings over wood subfloors is demonstrated by a comparison of figures 11 and 13. The use of a felt underlay will cause a felt-base floor covering to be more susceptible to permanent indentations; but at the same time it will improve the comfort value of the installation, give a more even surface and thus less concentrated wear, and permit easy removal for replacement.

Many floor coverings, due to their nature and size, need to be bonded to a subfloor. The importance of a good bond must be emphasized. Failure in adhesion to the subfloor has a considerable effect on the ability of the floor covering to withstand service. Of the adhesives tested, the alumina cement-latex adhesive, the oil-base cement, the rubber cement, and lignin paste, in conjunction with the particular floor coverings used, showed good adhesive strength and durability. Resistance to moisture was not included in this test. The asphalt adhesives did not have sufficient adhesive strength or resistance to shearing stresses to prevent the curling and displacement of thin floor coverings in tile form.

A performance test on additional floor coverings and adhesives is in progress.

VII. SELECTED REFERENCES

[1] H. L. Dryden, Research on Building Materials and Structures for Use in Low-Cost Housing, NBS Building Materials and Structures Report BMS1 (1938). 10¢.

[2] P. A. Sigler and E. A. Koerner, Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1, NBS Building Materials and Structures Report BMS34 (1939). 10¢.

[3] W. E. Emley and C. E. Hofer, *Test of floor coverings for post-office workrooms*, J. Research NBS **19**, 567 (1937) RP1046. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 10¢.

[4] Investigation of Low-Cost Floor Coverings, NBS Letter Circular LC502 F. May be obtained free from the National Bureau of Standards, Washington, D. C.

[5] P. A. Sigler and Myrtle B. Woodward, Indentation and Recovery of Low-Cost Floor Coverings, NBS Building Materials and Structures Report BMS14 (1939). 10¢.

Washington, September 30, 1939.

○

BUILDING MATERIALS AND STRUCTURES REPORTS

On request, the Superintendent of Documents, United States Government Printing Office, Washington, D. C., will place your name on a special mailing list to receive notices of new reports in this series as soon as they are issued. There will be no charge for receiving such notices.

An alternative method is to deposit with the Superintendent of Documents the sum of $5, with the request that the reports be sent to you as soon as issued, and that the cost thereof be charged against your deposit. This will provide for the mailing of the publications without delay. You will be notified when the amount of your deposit has become exhausted.

If 100 copies or more of any report are ordered at one time, a discount of 25 percent is allowed.

Send all orders and remittances to the *Superintendent of Documents, United States Government Printing Office, Washington, D. C.*

The following publications in this series are available by purchase from the Superintendent of Documents at the prices indicated:

BMS1	Research on Building Materials and Structures for Use in Low-Cost Housing	10¢
BMS2	Methods of Determining the Structural Properties of Low-Cost House Constructions	10¢
BMS3	Suitability of Fiber Insulating Lath as a Plaster Base	10¢
BMS4	Accelerated Aging of Fiber Building Boards	10¢
BMS5	Structural Properties of Six Masonry Wall Constructions	15¢
BMS6	Survey of Roofing Materials in the Southeastern States	15¢
BMS7	Water Permeability of Masonry Walls	10¢
BMS8	Methods of Investigation of Surface Treatment for Corrosion Protection of Steel	10¢
BMS9	Structural Properties of the Insulated Steel Construction Co.'s "Frameless-Steel" Constructions for Walls, Partitions, Floors, and Roofs	10¢
BMS10	Structural Properties of One of the "Keystone Beam Steel Floor" Constructions Sponsored by the H. H. Robertson Co	10¢
BMS11	Structural Properties of the Curren Fabrihome Corporation's "Fabrihome" Constructions for Walls and Partitions	10¢
BMS12	Structural Properties of "Steelox" Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Steel Buildings, Inc	15¢
BMS13	Properties of Some Fiber Building Boards of Current Manufacture	10¢
BMS14	Indentation and Recovery of Low-Cost Floor Coverings	10¢
BMS15	Structural Properties of "Wheeling Long-Span Steel Floor" Construction Sponsored by the Wheeling Corrugating Co	10¢
BMS16	Structural Properties of a "Tilecrete" Floor Construction Sponsored by Tilecrete Floors, Inc	10¢
BMS17	Sound Insulation of Wall and Floor Constructions	10¢
BMS18	Structural Properties of "Pre-Fab" Constructions for Walls, Partitions, and Floors Sponsored by the Harnischfeger Corporation	10¢
BMS19	Preparation and Revision of Building Codes	15¢
BMS20	Structural Properties of "Twachtman" Constructions for Walls and Floors Sponsored by Connecticut Pre-Cast Buildings Corporation	10¢
BMS21	Structural Properties of a Concrete-Block Cavity-Wall Construction Sponsored by the National Concrete Masonry Association	10¢
BMS22	Structural Properties of "Dun-Ti-Stone" Wall Construction Sponsored by the W. E. Dunn Manufacturing Co	10¢
BMS23	Structural Properties of a Brick Cavity-Wall Construction Sponsored by the Brick Manufacturers Association of New York, Inc	10¢
BMS24	Structural Properties of a Reinforced-Brick Wall Construction and a Brick-Tile Cavity-Wall Construction Sponsored by the Structural Clay Products Institute	10¢
BMS25	Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs	15¢
BMS26	Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Co., Inc	10¢
BMS27	Structural Properties of "Bender Steel Home" Wall Construction Sponsored by The Bender Body Co	10¢
BMS28	Backflow Prevention in Over-Rim Water Supplies	10¢
BMS29	Survey of Roofing Materials in the Northeastern States	10¢
BMS30	Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association	10¢
BMS31	Structural Properties of "Insulite" Wall and "Insulite" Partition Constructions Sponsored by The Insulite Co	15¢
BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	10¢
BMS33	Plastic Calking Materials	10¢
BMS34	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1	10¢
BMS35	Stability of Sheathing Papers as Determined by Accelerated Aging	10¢

[List continued on cover page IV]

BMS36	Structural Properties of Wood-Frame Wall, Partition, Floor, and Roof Construction with "Red Stripe" Lath Sponsored by The Weston Paper and Manufacturing Co.	10¢
BMS37	Structural Properties of "Palisade Homes" Constructions for Walls, Partitions, and Floors Sponsored by Palisade Homes	10¢
BMS38	Structural Properties of Two "Dunstone" Wall Constructions Sponsored by the W. E. Dunn Manufacturing Co.	10¢
BMS39	Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Co.	10¢
BMS41	Effect of Heating and Cooling on the Permeability of Masonry Walls	10¢
BMS43	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2	10¢